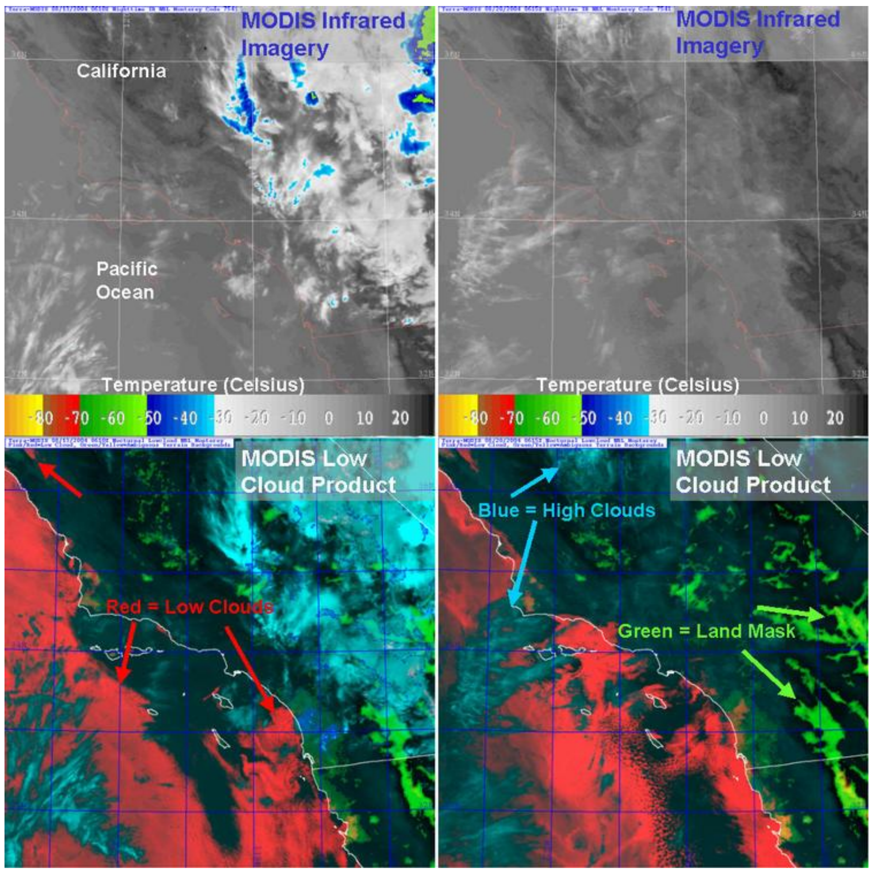
Satellite Product Tutorials:

Low Clouds at Night



Above: The nighttime low cloud product simplifies in most cases the detection of marine layer clouds and coastal/inland fog banks at night by color-coding these features in the scene as red. In the examples above, conventional infrared imagery (top panels) fails to reveal the detail of low cloud cover (lower panels; red) throughout the scene. Contemporary operational sensors easily exploit the physics allowing for this technique. However, important exceptions to the straightforward interpretation of the product occur. The current application of the traditional low cloud detection product makes allowance for these exceptions through additional color-coding of "potential problem areas" as green.

Why We're Interested…

Poor visibility due to fog claims lives in automotive accidents every year (a recurrently severe example being the "Tule fog" forming along the Interstate-5 corridor through California's San Joaquin Valley). Low clouds and fog also pose serious hazards to aircraft by obscuring runways and low-altitude flight hazards—leading to flight delays, airport diverts, cancellations, and even flight mishaps. The disorienting effects of these seemingly benign clouds make them in some respects more dangerous than severe weather systems.

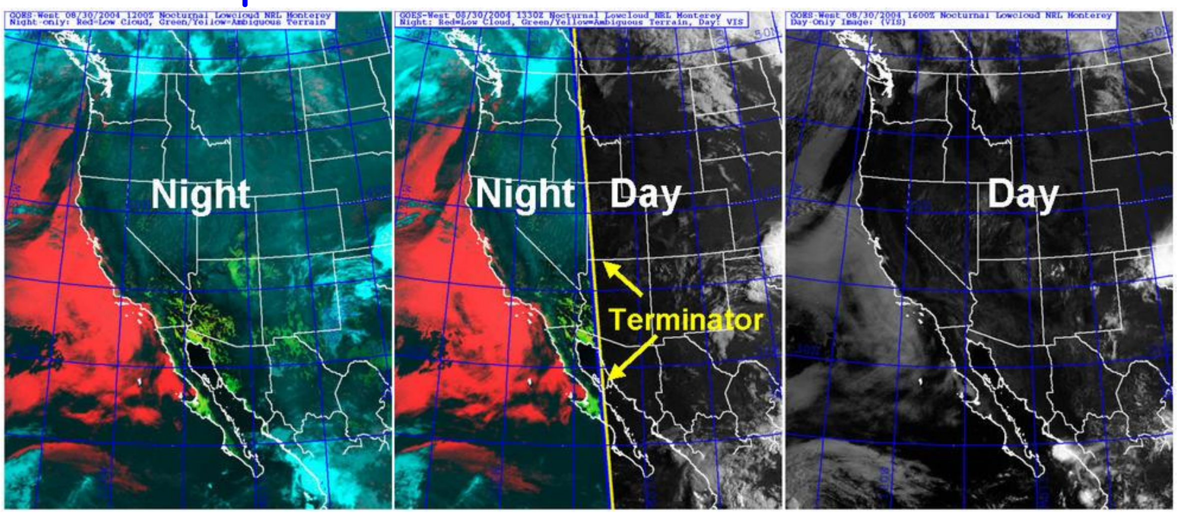
How This Product is Created…

During daylight hours, sunlight reflection off clouds enables their detection from visible imagery. At night, a common approach to cloud detection is to look for temperature contrasts between clouds and the surface. Higher clouds are usually colder than the land/ocean and provide good temperature contrast. Low clouds, however, pose a challenge since they tend to have temperatures *similar* to that of the surface (and in some cases, particularly over land, can actually be warmer). Here, we must rely on properties of the clouds themselves rather than simple temperature contrasts in order to infer their presence.

To detect clouds at night, we use a difference in temperatures measured in two different bands of radiation. In one band (11.0 μm), the cloud behaves as a "perfect emitter" and the temperature measured represents the actual temperature of the cloud, while in the other band (4.0 μm) the cloud is not a perfect emitter and so the temperature measured is somewhat lower. The 11.0-4.0 μm brightness temperature difference is therefore positive, and we use classify these areas as low cloud. The physics behind this enhancement results in preferential highlighting of low clouds comprised primarily of smaller droplets (~8 μm).

The 11.0-4.0 μm difference technique works well over the water, but over land there are certain soil types (particularly of the high mineral content variety, abundant in the deserts of the southwestern United States) that produce a signal similar to the low cloud signature we're after. These areas may trigger "false alarms" for low cloud. One method to deal with this problem is to try flagging these false-alarm areas in the scene ahead of time. By examining the same area night after night, we observe clouds to be random and intermittent, while soil signals are persistent. Over time and many observations we can tally the number of times a given area reported a "cloud" being present and arrive at a reasonable estimate of where the false-alarm soil areas reside. Then, we can try to mitigate their effects on the low cloud product.

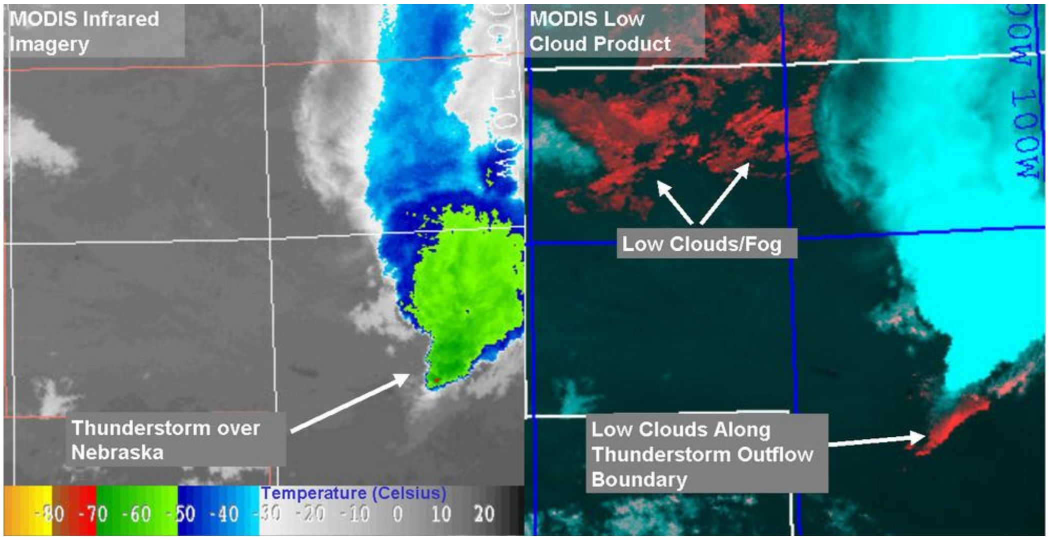
How to Interpret…



An example of this method, applied to the west coast of the United States, is shown above. In the enhancement, low clouds appear red, high clouds appear cyan, and regions of potential false alarms (the land mask) appear green. Without the mask, many regions over the southwestern deserts would appear red, similar to the low clouds. Actual low clouds overriding masked regions are necessarily considered "ambiguous," although in practice they may be detected if the strength of their signal is substantial (in this case, they produce a yellow tonality over the otherwise lime-green mask). This example is taken from the GOES imager, which offers updates every 30 minutes but at coarser spatial resolution than the AVHRR and MODIS polar orbiting sensors.

What to Look For:

Over the NexSat domain, low cloud fields are most abundant off the west coast of the United States. The clouds form beneath a low level "capping inversion" (so-called because descending and warming air from a persistent high pressure system over the northern Pacific Ocean gives rise to a stable layer in the lower atmosphere which defines a limit to how high marine clouds can grow) and can persists for days, weeks, or even months (especially during the summertime months). Over land, less regular patterns of low cloud formation occur with even stronger seasonal and diurnal (day vs. night) patterns. Examples include radiation and advection fogs over Texas, the Great Lakes, and the central valley of California as previously mentioned.



The previous examples have focused on low clouds over the ocean. The example above demonstrates the utility of the low cloud product over land. Here, the product reveals two sets of low cloud features over Nebraska that are discernable only through ad-hoc comparison in the infrared imagery. The red line to the south of the highlighted thunderstorm (as noted by the cold cloud tops in the infrared image) denotes clouds formed along the outflow of cool air from the heavy precipitation core of the thunderstorm. The outflow is sometimes referred to as the "gust front" and the clouds formed from the gust front are called arcus, or roll-clouds. In other examples pertaining to severe weather, the low cloud product reveals "hail fog," which occurs when signicant amounts of hail cool the air near the surface to the dewpoint temperature.

Things to Watch Out For:

Rare errors in satellite geolocation can result in a shifting of the satellite data with respect to the mask, revealing some of the problem areas. Clouds in pristine environments may be enhanced or only weakly or missed altogether, due to their larger droplet sizes and weaker scattering behavior. Variations in the amount of water vapor in the lower atmosphere are responsible for slight changes (brightening/darkening, but not spatial extent) in the appearance of masked regions. Although the effect is often subtle, some masked land regions may become yellow under conditions of higher water vapor. These instances can usually be differentiated from low clouds traversing a mask region simply by inspecting the imagery for indications of low cloud outside of the mask regions.

Looking Toward the NPOESS Era…

The National Polar-orbiting Operational Environmental Satellite System (NPOESS) Visible/Infrared Imager/Radiometer Suite (VIIRS) will provide the bands required to continue nighttime low cloud detection. An area of ongoing research is determining whether additional channels to become available upon VIIRS (for example, the 8.5 micron channel for assisting in liquid/ice cloud discrimination, and the nighttime visible band for cloud detection based on moonlight-reflection) will be useful in further isolating the low cloud signal and enabling the removal of the land-mask altogether.

Did You Know…?

By reflecting a substantial portion of incoming sunlight back to space, the persistent low cloud decks covering many parts of the world's oceans play an important role in determining the climate. How reflective these clouds are is related to the average size of the individual cloud droplets comprising them (clouds having smaller droplets are typically more reflective than those having larger ones). In polluted environments, cloud droplet sizes tend to be smaller and the clouds more reflective, while in pristine-air environments the opposite is true. This is another example of how humans (through atmospheric pollution, for example, from automobiles) unwittingly and inadvertently impact the climate in significant and potentially adverse ways through every day activities like driving cars or using fossil-fuel-based power sources to cook a meal or take a hot shower.

Want to Learn More?

View an online tutorial on Polar Satellite Products (includes low clouds)
Read more details on the development of this product.

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